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Development of Characterization Tools for Contaminated Nuclear Stacks

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ABSTRACT

The stack decommissioning processes have been explained at irregular intervals in procedural literature; there is almost no complete treatment of dismantling and decommissioning methods for contaminated chimneys. In addition, the International Atomic Energy Agency (IAEA) has published only one technical report that really focuses on this subject [1]. The dismantling of contaminated stacks at nuclear facilities is one of the least approached topics in the decontamination and decommissioning (D&D) field. The demolition of several stacks located at Oak Ridge National Laboratory (ORNL) is on the priority list of D&D activities at this national laboratory. Decommissioning is the final stage of the life-cycle for a nuclear facility after its design, construction, commissioning and operation. The decommissioning process involves decontamination operations, dismantling and demolition. Also, decommissioning techniques are mainly driven by the results obtained in the process of characterization. The main purpose of the characterization process is to gather enough data to evaluate the radiological status of the nuclear plant or facility and to better understand the level of contamination. To characterize a nuclear stack, a systematic procedure is used. First, the stack is divided into four sections by height, each section is zoned into four quadrants, and samples and measurements are taken in each quadrant by applying different mechanical procedures. These samples and measurements are collected and evaluated to estimate the levels of contamination inside of the stack. This presents an engineering challenge: to design a mechanism capable of swiping, drilling, collecting, and coordinating locations. There are several companies that offer alternative technologies for the characterization process; however, very few are applicable to high elevations and cylindrical structures.

In the process of nuclear stacks characterization, the transferable contamination survey or swiping is fundamental. The transferable contamination survey or swiping is an assessment of the amount of readily removable contamination present on a surface. For several reasons, in the case of nuclear stacks, the application of this conventional technique becomes a lot more complicated. The poor condition of the structures, which represents the case for most of the stacks at every nuclear facility of the Department of Energy (DOE), does not allow the direct participation of workers during the implementation of this contamination test. For this reason, the need for a remote technique emerges, in order to protect the safety of the workforce. In order to meet the needs of this difficult task inside of a nuclear stack environment, a conceptual design for a swipe mechanism has been proposed by the Robotics group of ORNL. The mechanism will allow for the collection of several swipe samples during each deployment of the system. In this technical paper, the experimental procedures implemented in order to select the most suitable swipe material will be presented. The stacks' physical conditions and the rough surface of the inner walls will not allow for the use of conventional materials. This brought a great challenge to the selection process and required the creation of surfaces similar to those found in the nuclear stacks as well as the loose contaminants encountered in them. The swipes materials were evaluated to determine the amount of transferrable material collected. The results were then compared and a final material was selected and recommended for implementation.

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1. INTRODUCTION

Elevated nuclear stacks are one of the most common structures present at nuclear sites. Their main purpose is to weaken and disperse the permitted airborne release from the active plant system. Environmental regulations stipulate the design of these elevated structures; this is for the safety of the personnel that work at the site as well as for the local area outside the site. The stack's height depends on several factors, such as the surface type and height of nearby buildings, weather conditions, and the potential nuclear capacity of the facility. These factors can result in a needed stack height of over 300 feet. Also, depending on the facility and its use, stacks are made of different materials, such as brick, concrete and reinforced steel.

Stacks become contaminated due to continuous use throughout the life-cycle of the nuclear facility. Depending on the levels of contamination and the physical conditions, the decommissioning of a nuclear facility can vary from a simple to a more complex level of difficulty. For these reasons, characterization is a key factor in the development of a decontamination and decommissioning (D&D) plan at a nuclear site. The characterization process consists of collecting data to identify the physical and chemical characteristics of the structure being analyzed. This database will help the decommissioning planner to choose the best strategy for the specific site. Due to the big challenges brought about by D&D activities in the past, several technologies have been developed in the last decades to ease decommissioning operations. However, because of several factors, such as specific shape, height and accessibility, nuclear stacks are a new challenge for this field. In addition, the location of the stacks within the nuclear complex adds another level of complexity into the D&D preparation; in many nuclear facilities, some of the stacks are built next to office buildings. For these cases, available technologies are limited and the levels of risk for the workforce within the complex are extremely high. In this technical report, the general process for characterization of nuclear stacks will be summarized as well as all the previous work related to the decommissioning of nuclear stacks in the United States. This report will also summarize the technology available on the market for D&D projects, pointing out the advantages and disadvantages of each.

The dismantling of the nuclear stacks located at Oak Ridge National Laboratory (ORNL) represents a great concern for the safety and protection of the workforce involved in the D&D process as well for the personnel that work in nearby offices. As shown in Figure 1, the stacks at ORNL are located within an office complex, thus requiring more elaborate and specific technologies than the ones actually offered in the market. A mechanism has been developed by the Robotics Department at ORNL that would characterize nuclear stacks in a remote manner. To make this process automated and remotely controlled, cameras and positioning sensors play a great part in the design. In addition, to make the robotic system economically efficient, it was designed to work for stacks within a large size range. A crane will be implemented for the deployment of the first model. The final mechanism was named the Stack Characterization System (SCS); this mechanism has the ability to stabilize itself inside of a cylindrical shape as shown in Figure 2. The three upper legs are the stabilizers of the system, while the remaining legs will carry the instrumentation needed for the characterization process (Figure 3 and 4). In this technical report, the characterization tools and their elements will be explained and verified in order to guarantee the efficiency of the entire SCS. First, the materials used for the smear mechanism incorporated into the SCS were tested as well as some of the electrical, mechanical and computer software elements. The second aspect approached in this report is the core drill mechanism to be incorporated into the SCS. A full mechanism was designed, satisfying all the considerations and needs for the core drilling operations in the SCS.

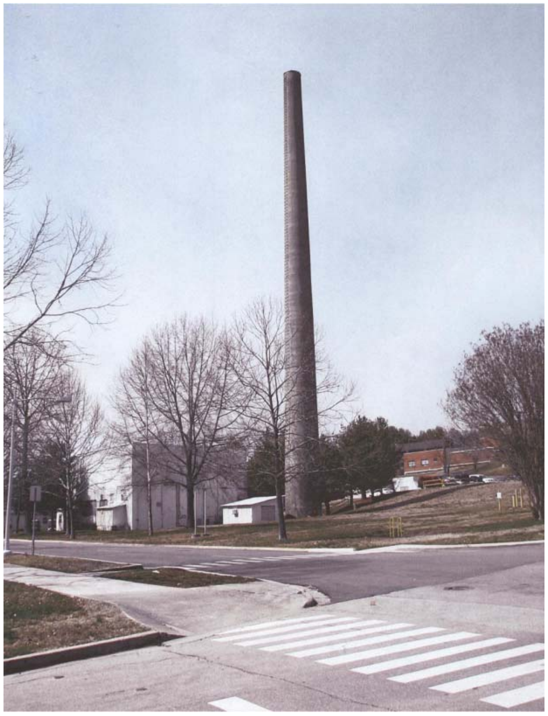

Figure 1. Stack number 2061 at ORNL.

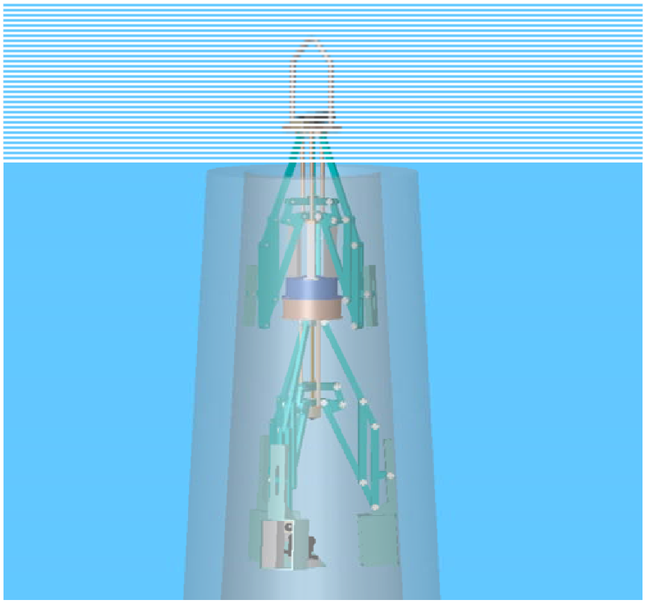

Figure 2. SCS deployment in upper portion of stack.

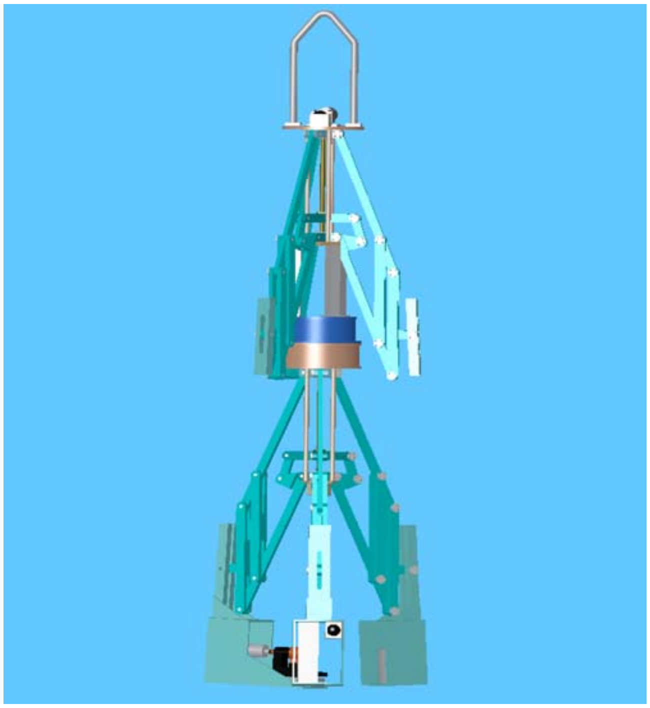

Figure 3. SCS mechanism in the semi-folded position.

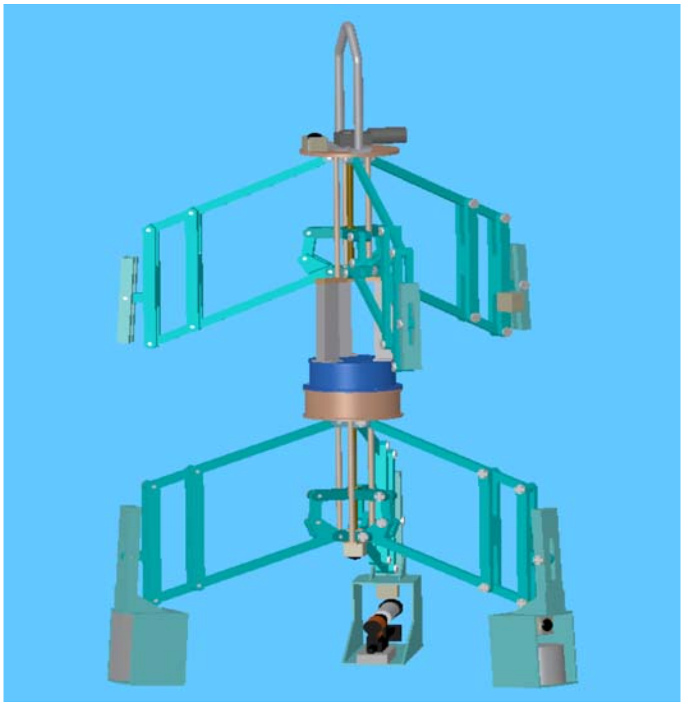

Figure 4. SCS mechanism extended for deployment against stack walls.

2. PROBLEM DESCRIPTION

Due to the limited literature information regarding stacks decommissioning, the development of a conceptual design presents an engineering challenge in terms of technical execution. The International Atomic Energy Agency (IAEA) has only published one technical report that discusses this matter; however, each case presented in this report represents a completely different test in the decommissioning planning. The stacks located at ORNL are within an active office complex that has been scheduled for demolition in the next ten years. Because of this constraint and the high levels of contamination, the demolition of the stacks must be done prior to the demolition of the nearby buildings. This puts the workforce currently working in the surrounding areas at a high risk. In addition, D&D activities for many of the projects previously completed on stacks were performed manually with direct human contact. This type of approach is not possible at ORNL due to the deteriorated infrastructure and radiological contamination of the majority of the stacks. Another factor that adds a high level of complexity to this project is the physical difference in materials and dimensions of each stack. The devices that are going to be used in the project must be able to quickly adjust to be successful for all stack sizes and material types.

3. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2010, a DOE Fellow intern (Mr. William Mendez) spent 10 weeks doing a summer internship at ORNL's Measurement Science & System Engineering Division under the supervision and guidance of Mr. Mark Noakes and Mr. Randall Linn. This internship was organized and directed by the Higher Education Research Experience (HERE) and the Oak Ridge Institute for Science and Education (ORISE). The intern's project was initiated in April 26, 2010, and continued through June 25, 2010, with the objective of analyzing the characterization process of contaminated stacks at nuclear facilities.

The process of characterization is the first step in the decommissioning of a nuclear facility. This process includes smear sampling, core drilling and nuclear contamination detection by radar. The Stack Characterization System (SCS) developed by the robotic group of ORNL will remotely execute these procedures. In order to ensure the efficiency of these remote operations, several modifications and innovations were done to the conventional procedures. The validation of these non-conventional techniques becomes one of the main concerns during the design stage of the characterization tools. For this reason, within the scope of work assigned to the intern, validation experiments for some of the elements of the SCS's smear sampler were given. In the case of the smear sampler, the material to be used on the smear pad was validated. Several pad configurations for the smear sampler were designed, including foam materials of different thickness as well as sticky materials with different levels of adhesiveness. After several experiments, an optimum pad configuration was chosen. Another aspect analyzed regarding the characterization tools of the SCS was the core drilling mechanism. The overall idea of this mechanism is to take several samples and safely hold them during the retrieving process. A complete design was developed and presented to the Robotics group of ORNL as an alternative or possible final mechanism to be incorporated into the SCS.

4. STACK DESCRIPTION

The general structural design of nuclear stacks has evolved over the past century. The design is driven by two major factors: **structural characteristics,** which include all the regulations regarding wind loads, snow, temperature and seismic loading; and **discharge characteristics**, which include the ventilation flow rate and dispersion necessities, which defines the stack's diameter and height. There are four main types of stacks: brick, steel, reinforced plastic, and reinforced concrete.

4.1 Brick Stacks

Brick stacks are considered the oldest type of construction. With the development of material properties, new types of bricks that are more acid resistant are being used. They need a thicker base than conventional stacks and the heights usually do not exceed 330 feet. These stacks are no longer built in new modern nuclear facilities.

4.2 Steel Stacks

There are three main sub-types of steel stacks:

1. Single wall, unlined – guyed and self-supported

   These are the simplest sub-type of steel stacks and are used for low temperature requirements. They use cables for support which make them less expensive to construct. Depending on the steel material, they can be very resistant to the nuclear acids.

2. Lined with firebrick, acid resistant brick

   These stacks are built for high temperature requirements and are resistant to heavy acids. For this reason, the structure is internally lined with a special material that protects the steel from these extreme conditions. The stack heights can exceed 400 feet.

3. Dual wall and with interior steel lining

   This particular type of stack is built when the internal discharge needs to be kept at a high temperature to prevent condensation in the stack and close-by areas. They are really limited in height and do not usually exceed 130 feet.

4.3 Reinforced Plastic Stacks

Reinforced plastic stacks are very light and small in size. They have a low thermal conductivity and a good acid resistance. The commissioning and decommissioning can be easily accomplished with a crane.

4.4 Reinforced Concrete Stacks

Reinforced concrete stacks represent the largest number in the nuclear industry. They usually represent a major challenge in their decommissioning due to their height, up to 410 feet, and mass, that in some cases exceed 2000 tons.

5. CHARACTERIZATION PROCESS

Precise physical and chemical characterization is a key factor in the selection of stack dismantling tactics and technologies. Physical characterization gives the essential elements for calculating the residual mechanical properties of the stack and the time period in which the structure can safely remain in place. Nevertheless, accessing an elevated structure to acquire samples for physical or chemical characterization purposes needs cautious consideration of industrial safety for the protection of the workforce and surrounded areas. Characterization activities in contaminated areas will involve radiological protection provisions. Most of the stacks have a port access into the interior of the structure; the opening of this gate can precipitate and disperse the in situ contamination. This is one of the issues that a decommissioning planner has to face for the protection of the personnel. In many cases, remote controlled techniques such as video-graphic and/or robots are deployed to overcome the personnel safety issue.

In the process of characterization, it should be noted that the technical reports related to the material discharged through a nuclear stack may be incomplete or outdated. The data obtained from the characterization process provides information that will help the decommissioning planner to establish whether the stack can be decontaminated in a cost-effective way. The depth of contamination through the inner wall is another important piece of information. The characterization process requires the use of a practical, effective, and efficient method. For example, instead of sampling the entire interior wall of the stack, which is also possible, the decommissioning planner may suggest the coring or swipe sampling of selected areas to obtain an accurate estimation of the level of contamination inside of the stack. As previously mentioned, the stack characterization affects the path of the whole D&D process, from the selection of technologies and techniques to the management of waste resulting from the D&D activities.

The stack will be characterized at four different heights, as shown in Figure 5.

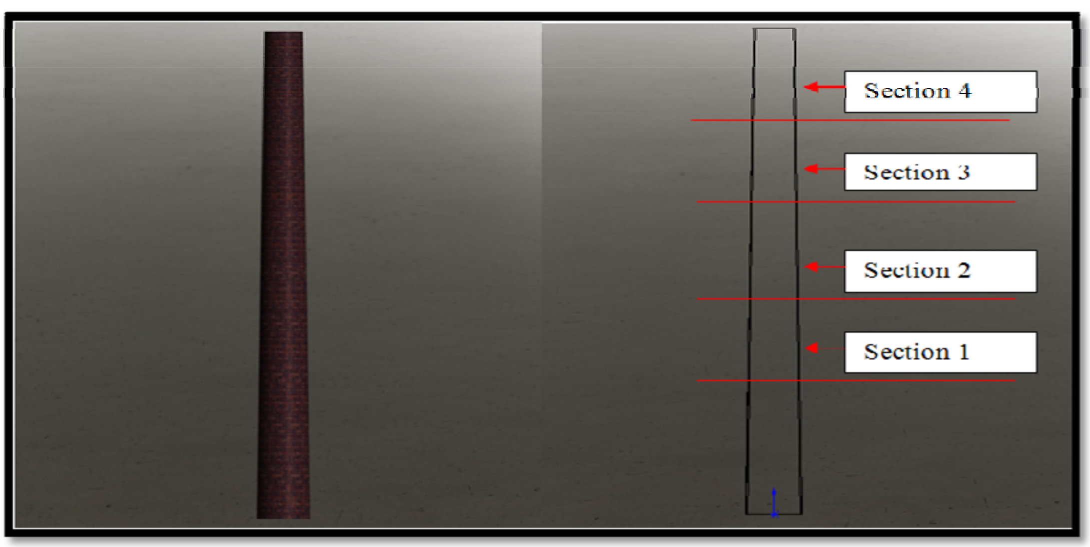

Figure 5. Nuclear chimney and section for characterization procedures.

At each section, three main operations must be done. First, the most contaminated quadrant of the section is identified with a scanning method as shown in Figure 6. Second, wall swiping and core drill sampling are done for the most contaminated quadrant. Third, for the remaining quadrants, just wall swiping is performed. This cycle is repeated for every section. Each sample collected must be stored and protected from cross contamination. For this reason, the samples are taken from the bottom of the stack to the top.

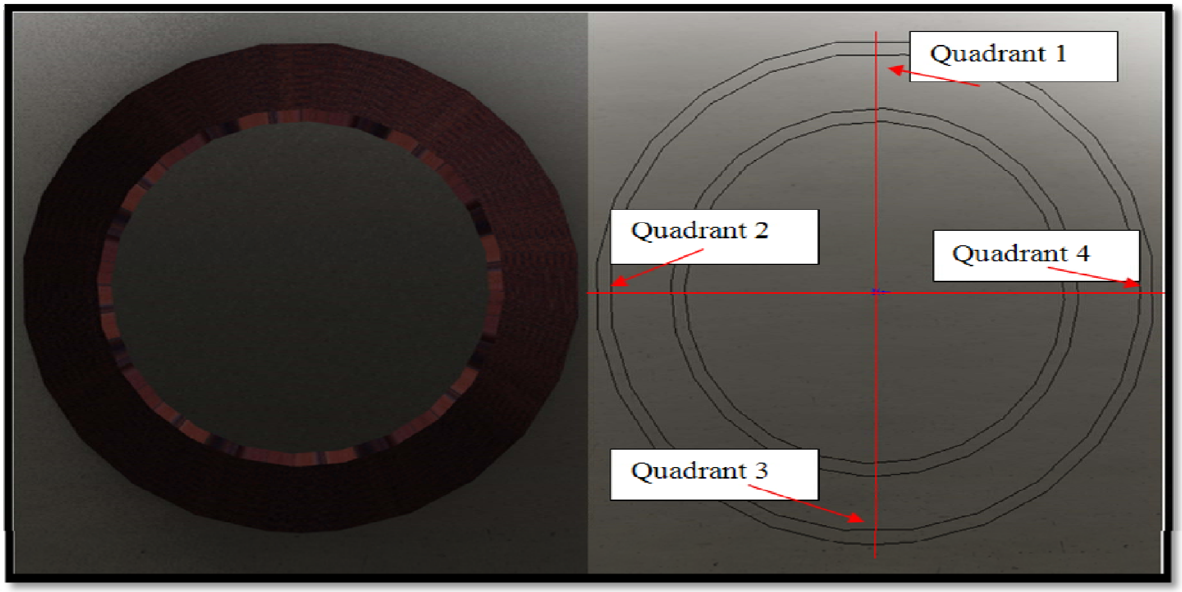

Figure 6. Top view of the nuclear stack and quadrants for characterization.

The mechanism is deployed by a crane to the top of the stack as shown in Figure 7. From there, using the data obtained from the physical characterization of the stacks, a positioning sensor is started at this fixed origin equalized to zero. Slowly, the device is set for the initial section at the base of the stack. The SCS mechanism is able to rotate respective to its axis, enabling it to perform all the previously mentioned operations.

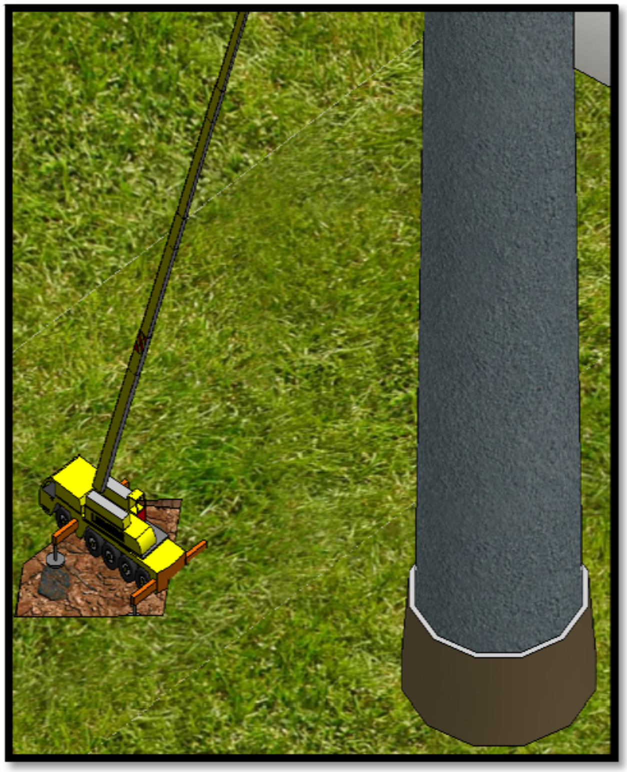

Figure 7. Crane located next to the stack to deploy the SCS.

6. PAD STUDIES FOR THE SMEAR SAMPLER OF THE STACK CHARACTERIZATION SYSTEM

6.1 Actuating Forces on the Smear Sampler - Experiment 1

The purpose of this experiment was to evaluate the force required to execute the smear sampling operation on various surface types. The experiment recorded the force implemented (tension and compression) during the smear sampling process. From this evaluation, several conclusions were made: reliability of the pad holder design and pad configuration (adhesive properties), linear actuator selection, and modifications required on the current design. The experiment was designed so that the smear sampler would be exposed to the actual conditions found inside of the nuclear chimney.

Foam padding was the material selected for this application as it has excellent absorption properties. Foam materials of different configurations and thickness were chosen. Foam with adhesive properties were also included as part of the configuration of the pads in order to enhance the collecting properties of the material. Figure 8 shows the regular foam (1" thick) and Figure 9 shoes the types of foam tape chosen.

Figure 8. Regular foam 1" thick.

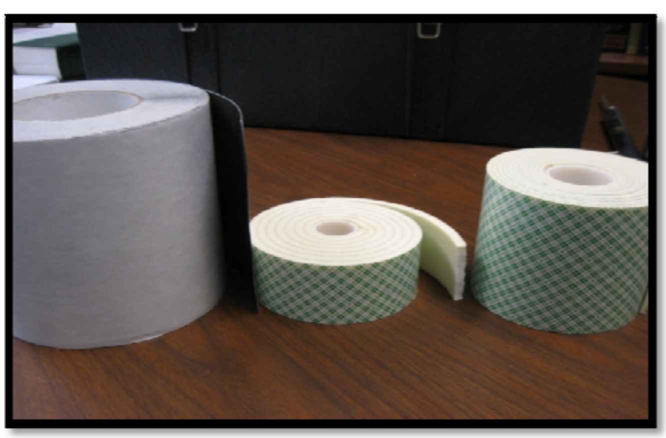

Figure 9. Double sided ribbon tape (left), double sided foam tape 1/4" thick (middle), double sided foam tape 1/8" thick (right).

The selection of test surfaces was done in such a way that the selected areas for the experiment would represent the inside environment of a nuclear chimney. The surface shown in Figure 10 is a rough surface located outside of the ORNL's robotics building.

Figure 10. Surface selected for the experiment.

The tension and compression forces were manually applied and measured with a spring scale. After every case, the tension force required to retrieve the adhesive pad was recorded. This allowed for the selection of the electrical linear actuator. The compression force was kept constant at 3 lb. Figures 11 and 12 show the compression and tension forces being applied, respectively.

Figure 11. Compression force applied (3 lbf).

Figure 12. Tension force applied (until retrieval of the pas is achieved).

In this experiment, the pads designed for the original smear sampler were modified and manufactured using a rapid prototype system. Figures 13 and 14 show the designs and configurations of the modifications.

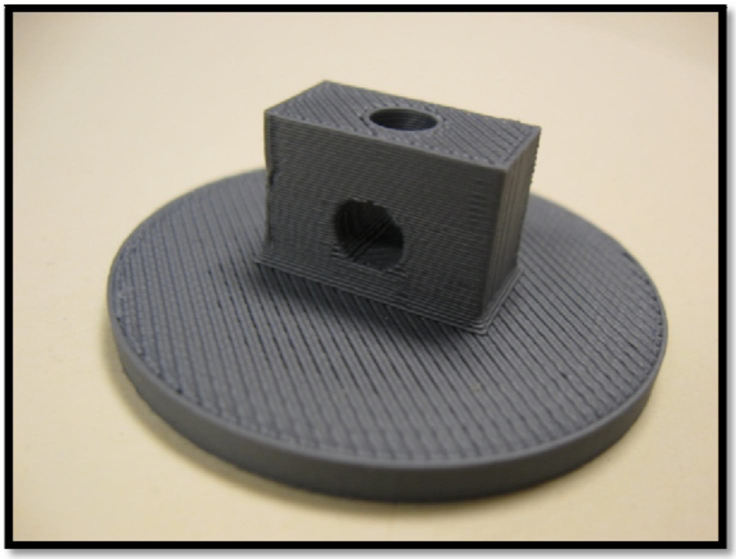

Figure 13. Frame for the pad used in the experiment.

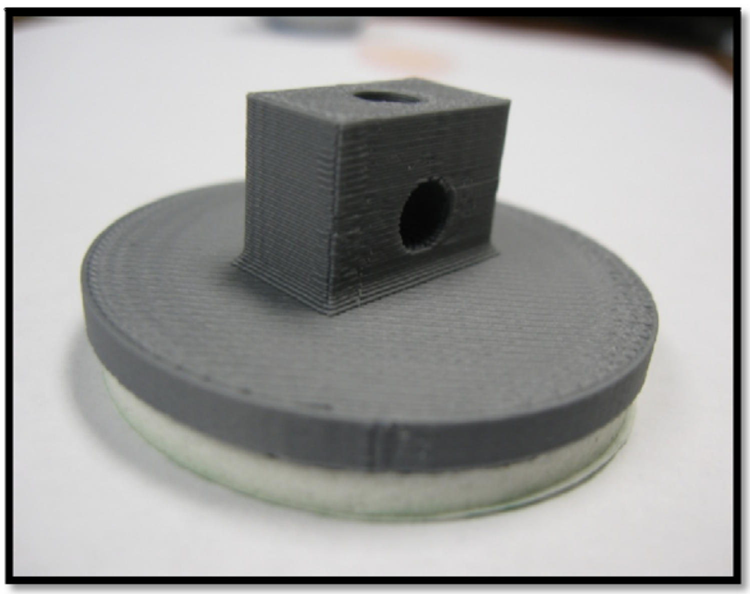

Figure 14. Pad frame and foam material with adhesive properties.

Figure 15. Recording data from spring scale.

Some of the pad configurations were immediately discarded after the experiment due to the amount of force required to separate them from the surface. Normally, it is expected to find a layer of dust on any given contaminated surface. However, hypothetically, the worst case scenario for which the highest amount of force is required to retrieve the pad is on a clean surface (free dust environment). This case is impossible to be encountered in the actual environment of a nuclear stack. The recommendation is to create a breaking mechanism for the pad's holder that would break and leave the pad on the wall once the linear actuator has reached its maximum force. Figure 16 shows how the pad configuration broke due to the amount of force required to retrieve it from the wall.

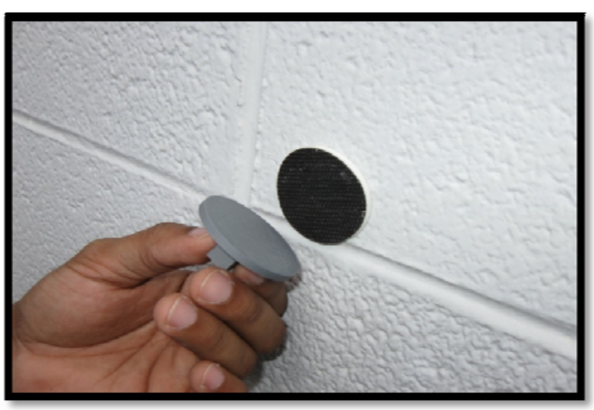

Figure 16. Breaking of the pad configuration due to high force applied to retrieve it.

Figure 17 shows how the adhesive layer of the foam partially ripped and remained on the wall. This and the previous case were tried on a clean surface. The lack of loose particles on the surface makes the bond between the adhesive material and the wall almost perfect; when this scenario is encountered, the forces required to retrieve the pad are relatively high.

Figure 17. Braking of the adhesive layer of the pad.

6.2 Data Collected from Experiment 1

Table 1. Data Collected from Experiment 1

	Pad Type	Applied Force (Compression) (Lbf)	Applied Force (Tension) (Lbf)	Observation
Dirty Rough	R-Fa-R	3	2.1	Dirt Collected **
	TSP	3	1.7	Dirt Collected **
	T_{sp}	3	0.9	Dirt Collected **
Clean Smooth	R-Fa-R	3	3.4	***
	TSP	3	10	***
	T_{sp}	3	10.3	***
Dirty Smooth	R-Fa-R	3	1.5	**
	TSP	3	2.5	***
	T_{sp}	3	5.2	***

R	Ribbon
TSP	Thin Sticky Pad
T_{sp}	Thick Sticky Pad
**	Removed Under 3.4 Lbf
***	Removed Over 3.4 Lbf
Fa	Foam

Table 1 provides the data collected from the first experiment. From these results, it can be concluded that the linear actuator of 3.4 lbf capacity used for the SCS's smear sampler can be kept as long as a breaking mechanism is implemented on the pad holder. This braking mechanism on the pad holder will prevent damaging the smear sampler in those cases where the tension force to retrieve the pads exceed the limit force of the actuator. The thick sticky pad configuration represented the best configuration for the smearing process; therefore, its use for the SCS's smear sampler is recommended.

6.3 Outdoor Testing -Experiment 2

The purpose of this experiment is to aid in the selection of the linear actuator (3.4 lb), the program interface for the smear sampler, and the performance of the designed mechanism for smear operations. In order to evaluate the SCS's smear mechanism, a functional setting was prepared to simulate the SCS's structure and a series of ideal surfaces were selected. Figure 18 shows how the smear sampler was arranged in order to execute this experiment.

Figure 18. Smear sampler set-up for the experiment.

The pads holders for this experiment were designed in a CAD software as well as the entire SCS. The pads of the smear sampler were manufactured using Fused Modeling Deposition technology (3D printer) which allows manufacturing parts in a strong ABS plastic, avoiding the long process of machining or other manufacturing techniques such as metal casting. Figure 19 illustrates some of the pad holders produced in the 3D printer.

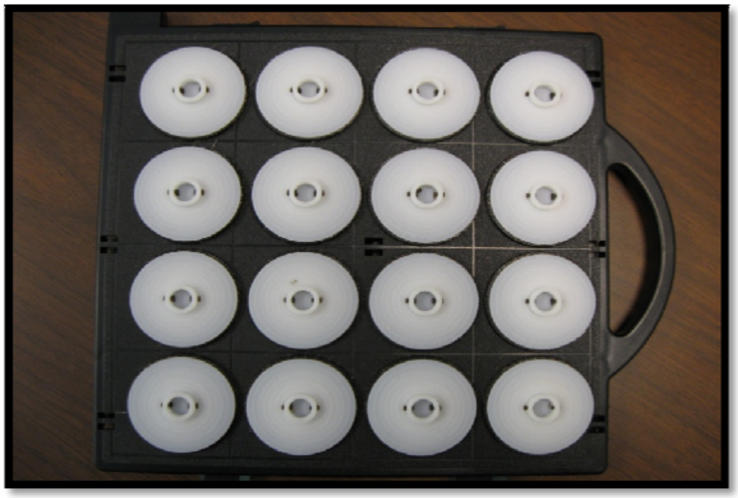

Figure 19. Pad holders manufactured for the experiment.

Another important element related to this experiment was the controlling systems for the mechanism. Once the smear sampler was designed and the electrical components pre-selected, computer software was used to create the interface between the user and the mechanism. Once the program was written, it was then uploaded into a computer and the controls connected to the mechanism are operated remotely via Ethernet. Figure 20 shows how the cables and pad holders were placed in order to complete the setup of the experiment.

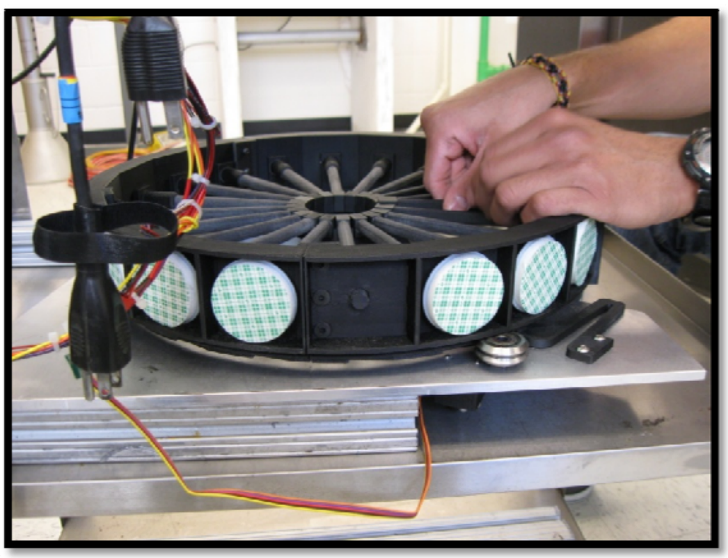

Figure 20. Controllers connected to the mechanical system of the SCS's smear sampler.

In order to ease the process of gathering samples, the mechanism was mounted on a wheeled cart and transported to the test surfaces. Figures 21 and 22 illustrate this process.

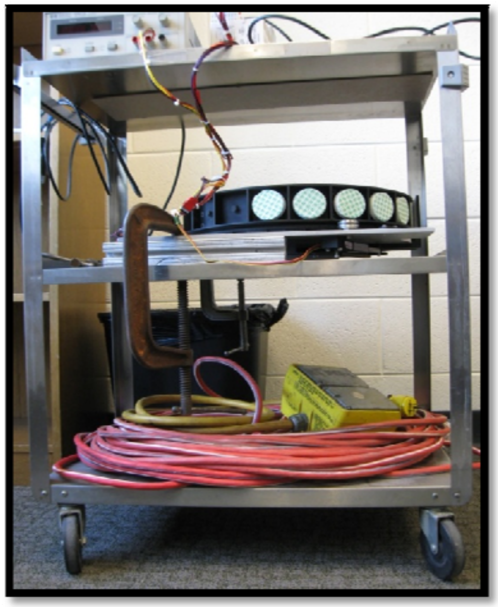

Figure 21. Wheeled cart used for the experiment.

Figure 22. Taking of a sample on a selected surface.

The selected electrical linear actuator proved to be sufficient for the forces in tension and compression needed for the smearing process. However, an initial recommendation from the previous experiment is kept. It is to create a breaking mechanism for the cases in which the tension force is not sufficient to retrieve the pad. Figure 23 illustrates the breaking point area in which the SCS's smear system could be re-designed.

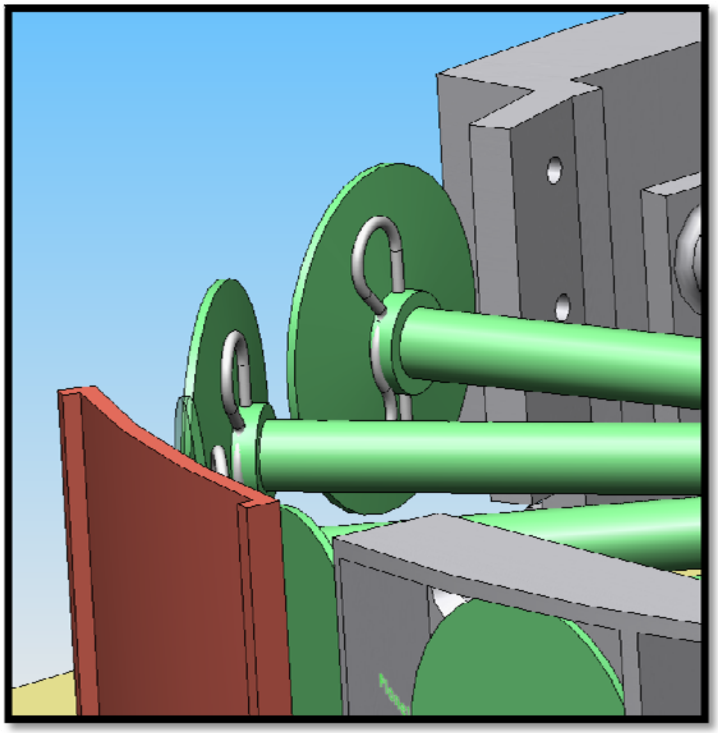

Figure 23. Recommendations for the re-design of the pad holder.

From both experiments, it can be concluded that some modifications should be done to the pad holder part of the smear sampler. This modification would allow for the use of a low power but yet efficient actuator. This will save energy usage, which is one of the main concerns in the overall project. The materials selected were proven to be efficient for the purpose of loose contaminant acquisition.

7. PROGRAM INTERFACE

The programming aspect of this project involved interfacing the operator located at the work station with the electrical elements of the SCS. The goal is to control the SCS's tools from a work station ensuring the safety of both the personal and the equipment. The program interface should also be able to save the data generated from the characterization operations. The DOE Fellows were asked to identify the capabilities of the software used for data logging. A data logging key was added to the already existing display for the smear sampler. This key would graph the input voltage given to each of the actuators used in the smear sampler. The data logged would save the time at which the sample was taken. Then, with a correlation between the input voltage and the fitting rate per voltage of the servo, the amount of extension or retraction of the actuator is known. The interface is similar to the one shown in Figure 24.

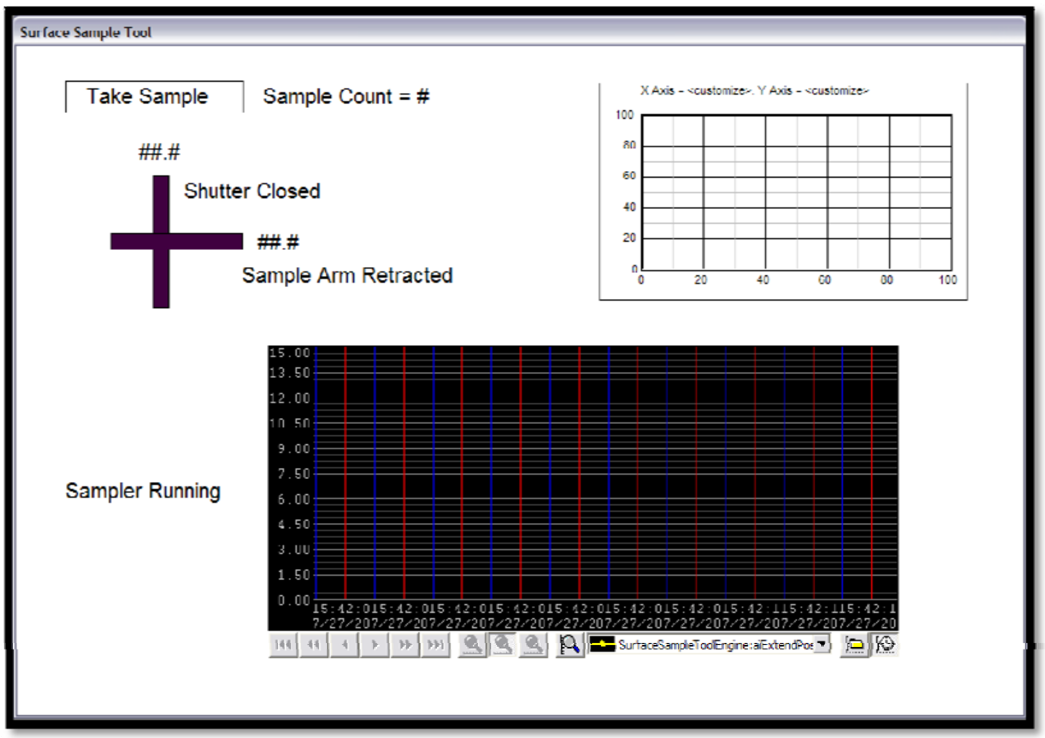

Figure 24. Software interface for the smear sampler.

The chart with the dark background and grid represents the voltage input to the "Shutter" and "Sample Arm Retracted" actuators. This input is recorded into a text file that indicates the voltage and the time that was delivered to the actuators. The data logged from this window interface will help during the data acquisition process of the SCS.

8. CORE DRILL DESIGN

The core drill design involved making a mechanism capable of taking several core samples in a single deployment of the SCS. The design should be mechanically efficient and easy to control. The design should be capable of integrating a vacuum system to absorb the dust produced by the drilling process. An electrical motor no less than 2 HP is needed to produce the rotation on the drill bit. In addition, a linear actuator of approximately 200 lbs will feed the drill bit to the wall while rotating. Finally, a frame will be designed to hold all of the elements listed above as well as provide additional space for batteries and other electrical elements.

8.1 Design of Core Drilling Mechanism (Assembly)

Figure 25 shows the full assembly of the proposed core drilling mechanism.

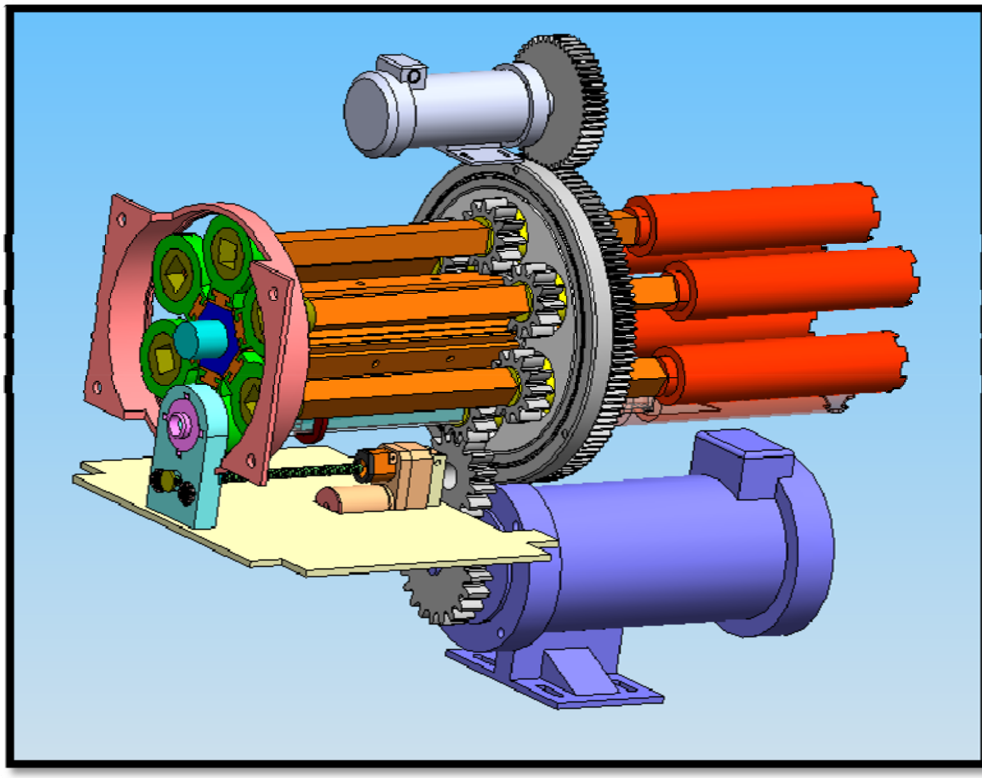

Figure 25. Full assembly of the proposed core drilling mechanism.

8.2 Rotating Disc

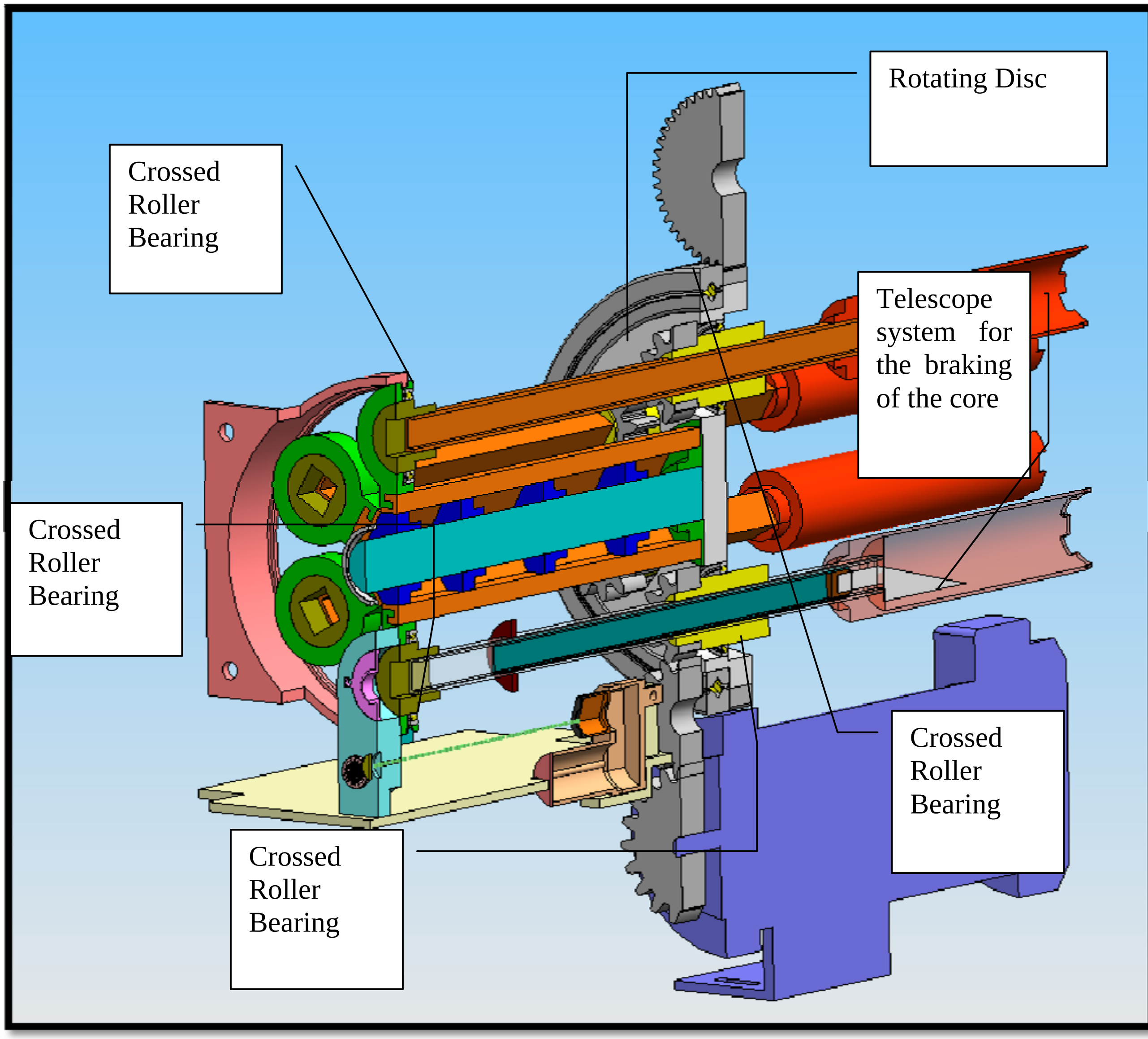

Figure 26. Main elements of the core drilling mechanism.

The rotating disc has six circular cuts to place the core drilling system (Figure 26). In the circular cut, a crossed roller bearing and shaft are size fitted. It is rotated by the upper motor, held by a crossed roller bearing (the one I used is considered a normal type crossed roller bearing); this bearing can be changed to a thin type and reduce the size of the circular cut on the frame that holds the rotating disc. The rotating disc connects with one side of the main shaft as shown in Figure 27.

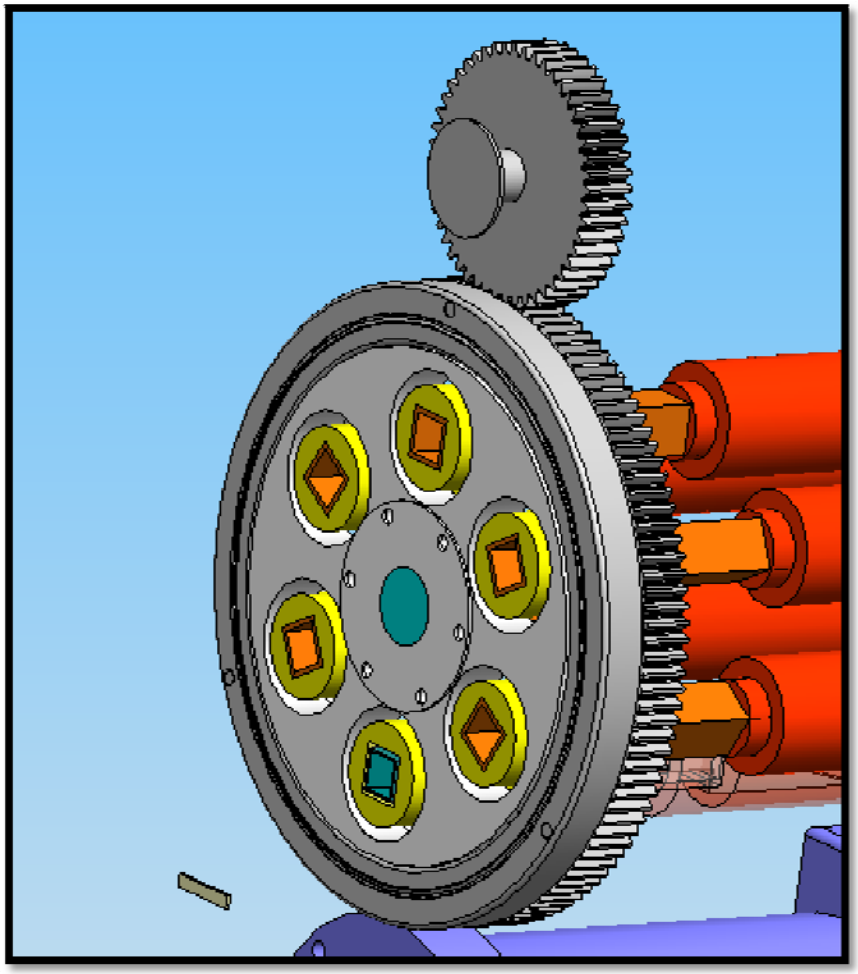

Figure 27. The rotating disk is driven by a small motor.

8.3 Main Shaft

The idea of the main shaft is to add support to the frame and reduce the moments on the disc while drilling. In addition, it works as a supporting frame for the guiders of the drill. It may be possible for these guiders to be redesigned to improve precision and to add reliability in the handling of forces due to the drilling operations. The blue hexagons shown in Figures 28 and 29 can be reduced in radius and the guiders can be increased in thickness. The number of blue hexagons can also be reduced; two may be enough in addition to the green hexagon that connects one end of the shaft with the rotating disc.

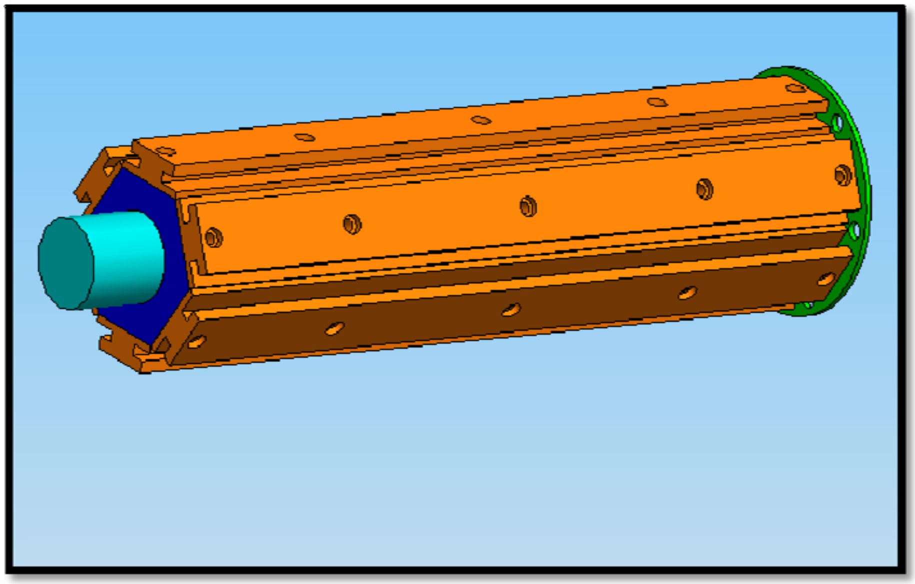

Figure 28. Driving shaft.

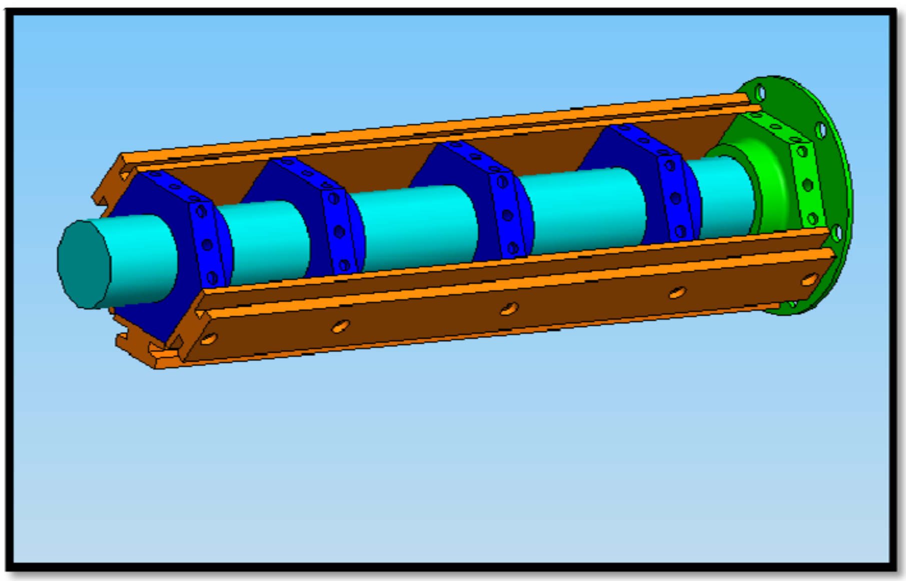

Figure 29. Internal elements of the driving shaft.

8.4 Drill Bits Guider

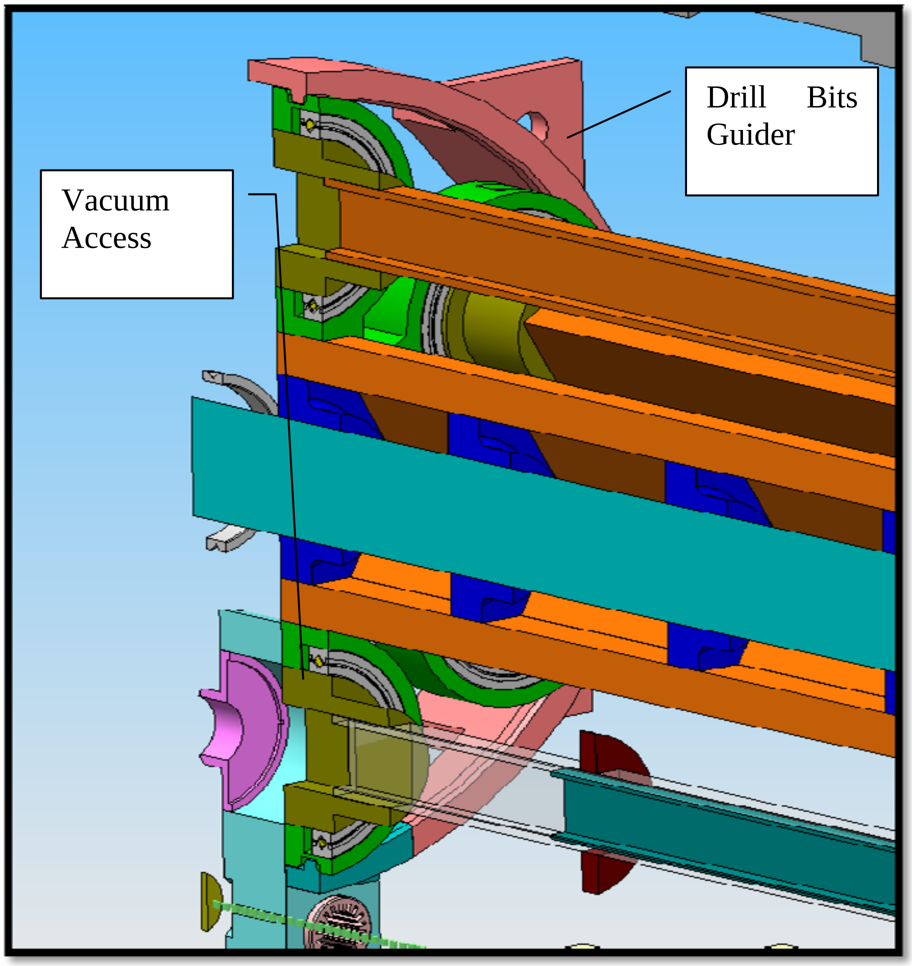

Figure 30. Drill bit guider and vacuum access.

A circular guider will be used for guidance of the parts during drilling operation (Figure 30). The drill bit guider protects the shafts from moving out of place while the drilling process is being implemented. It is bolted on to the main frame and it allows for easy rotation of the drill bits shaft in each operation as shown in Figure 31.

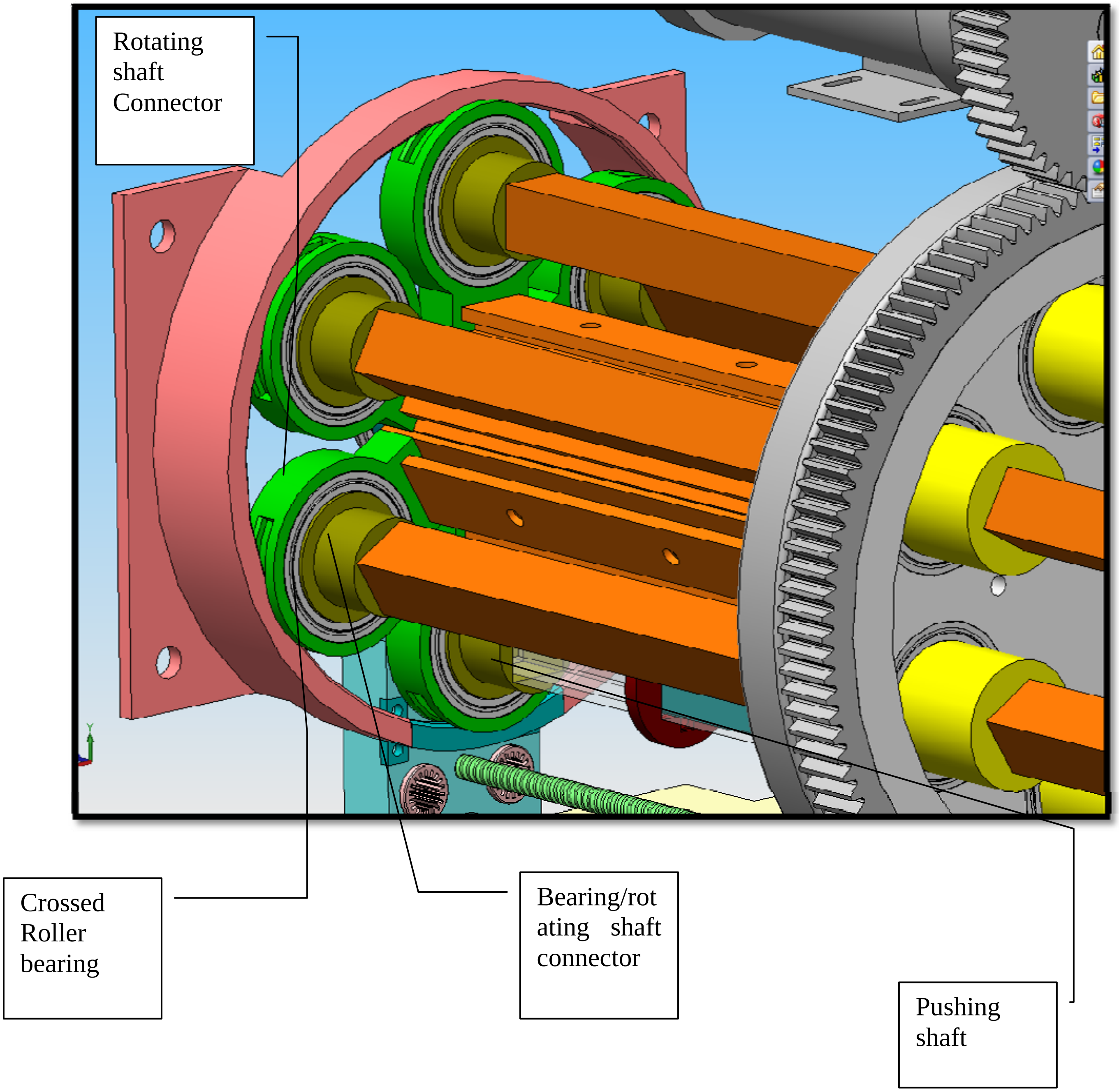

Figure 31. Elements of the drill bit guider.

8.5 Drill Bits Bearing A, Shaft and Pushing Actuator Connector

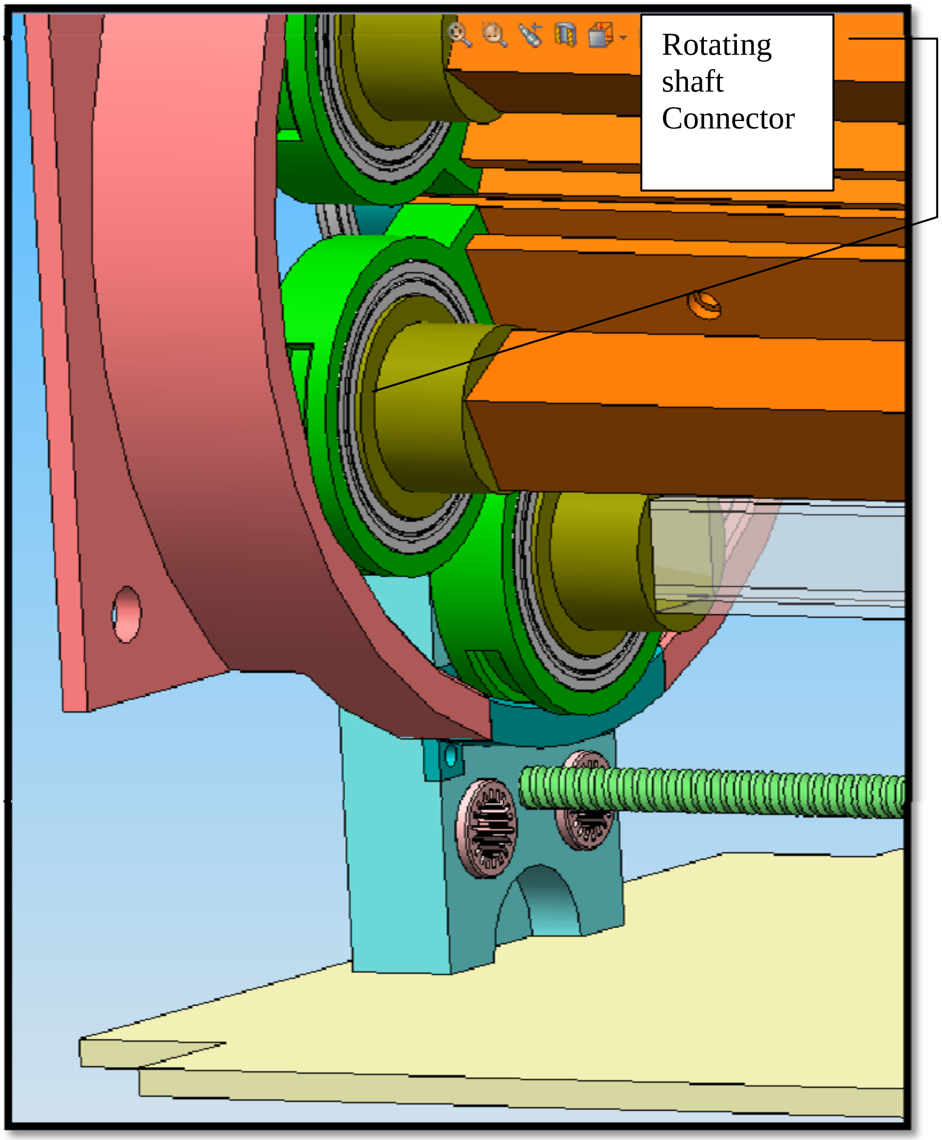

Figure 32. Rotating shaft connector.

The connector shown in Figure 32 allows for rotation of the shaft and the feeding action of the bit. The design can be improve to ensure reliability of handling both rotating and linear forces due to operations. Crossed roller bearings are used for the rotation of the shaft.

8.6 Drill Bits Bearing B, Shaft and Rotating Disk Connector

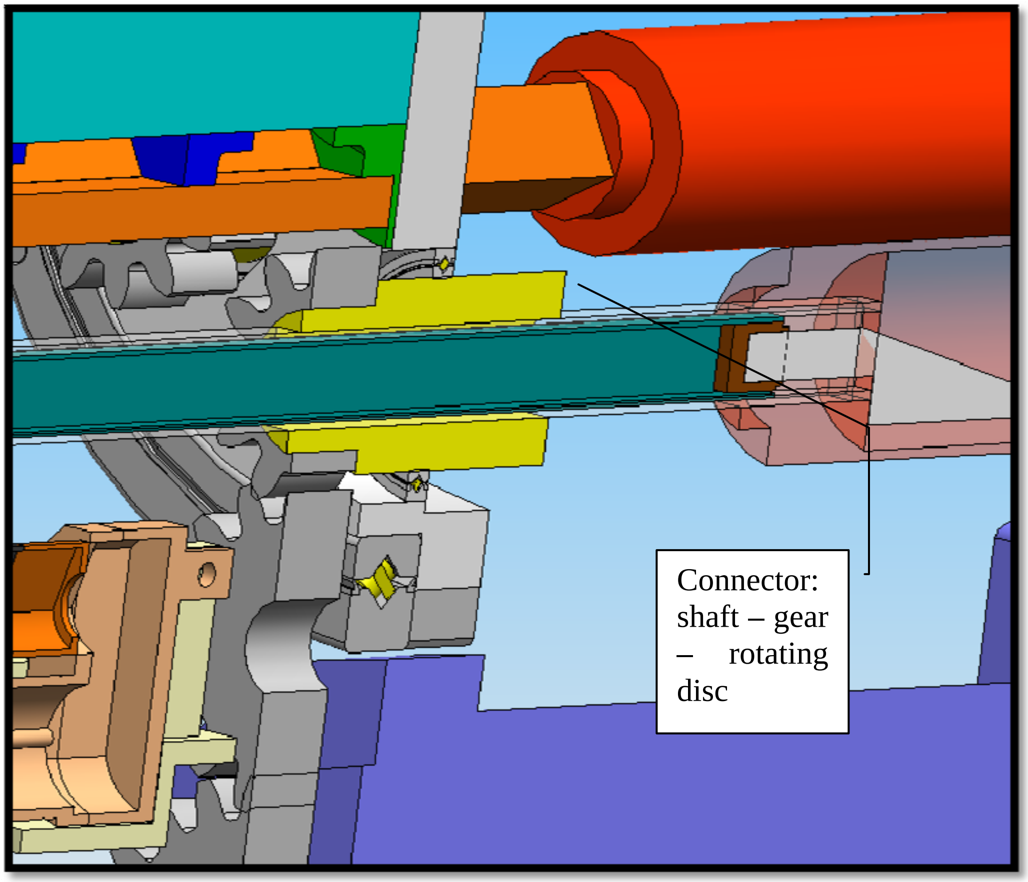

Figure 33. Connector: shaft – gear – rotating disc.

The connector shown in yellow in Figure 33 allows for the rotation of the shaft and feeding of the drill bit into the wall. A crossed roller bearing is used. Also notice the gear connected to it; this will allow the transmission of rotation from the driving motor placed below.

8.7 Pushing Actuator, Vacuum and Linear Bearing Connector

Plastic linear bearings will be used to reduce the moments produced for the pushing of the linear actuator and the contact with the shaft during the fitting action of the bit (Figures 34 and 35). The linear actuator is modified to improve space distribution. A drill bit guider is added to the part (Drill bit guider B) to complete the loop of the main drill bit guider.

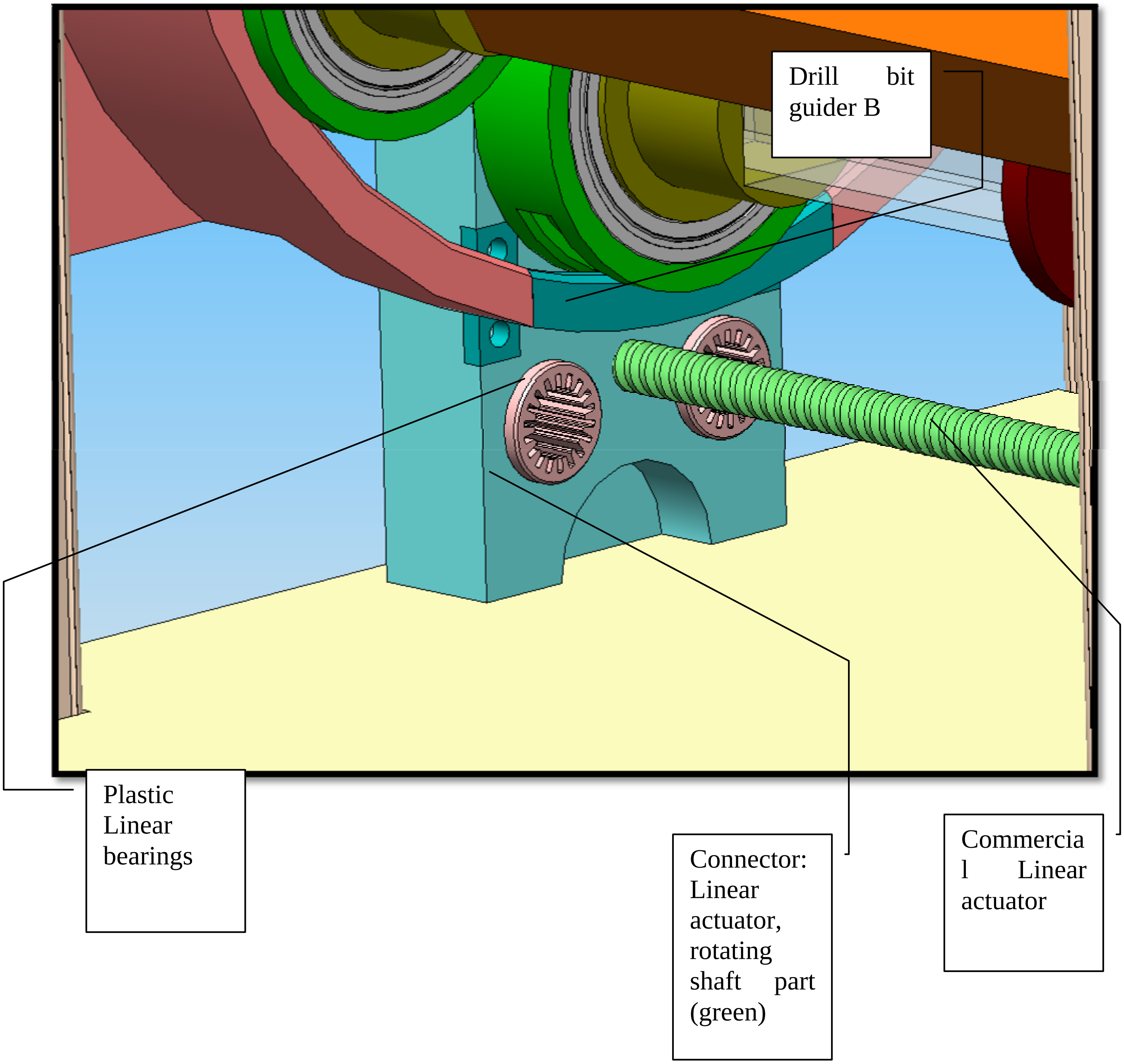

Figure 34. Pushing element for the core drill bit.

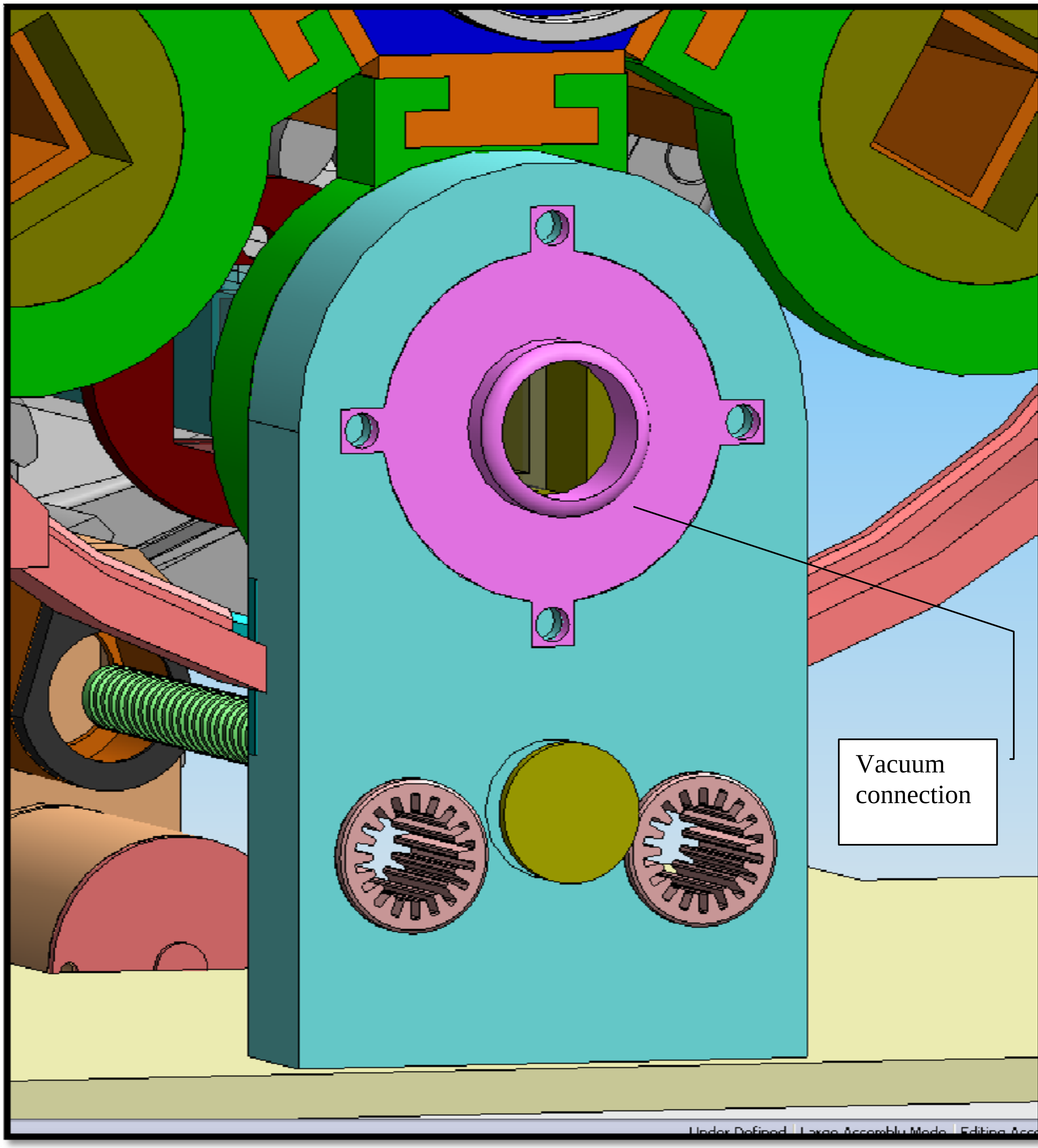

Figure 35. Rear view of the pushing element and vacuum connection.

8.8 Main frame

The main frame can be modified in thickness. The use of an 8020 type structure is proposed to add strength to the main frame (Figure 36 and 37). This will make the assembly of the components easier.

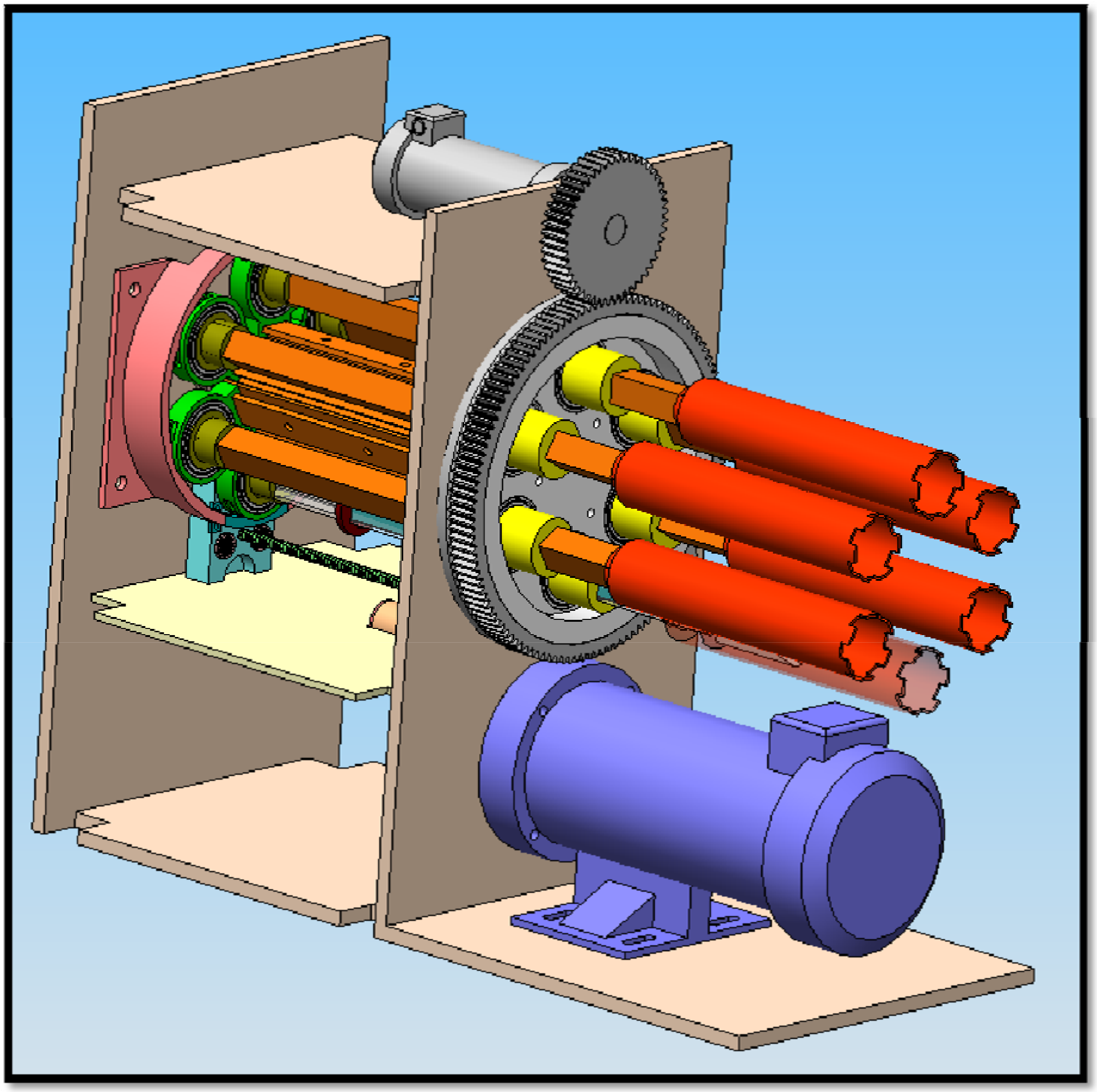

Figure 36. Frame for the core drill mechanism.

8.9 8020 Frame

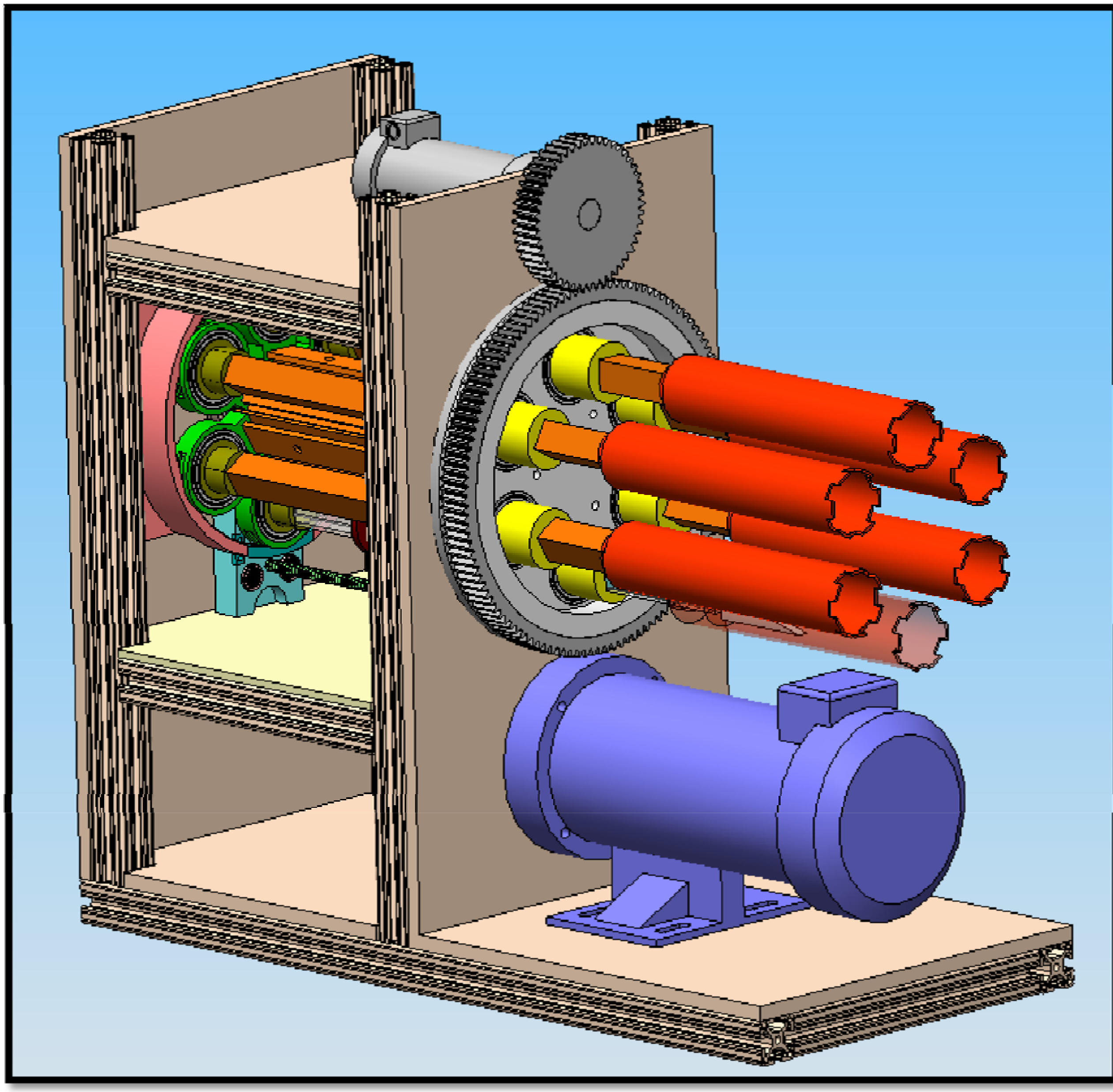

Figure 37 Frame for the core drill mechanism (8020 structure included)

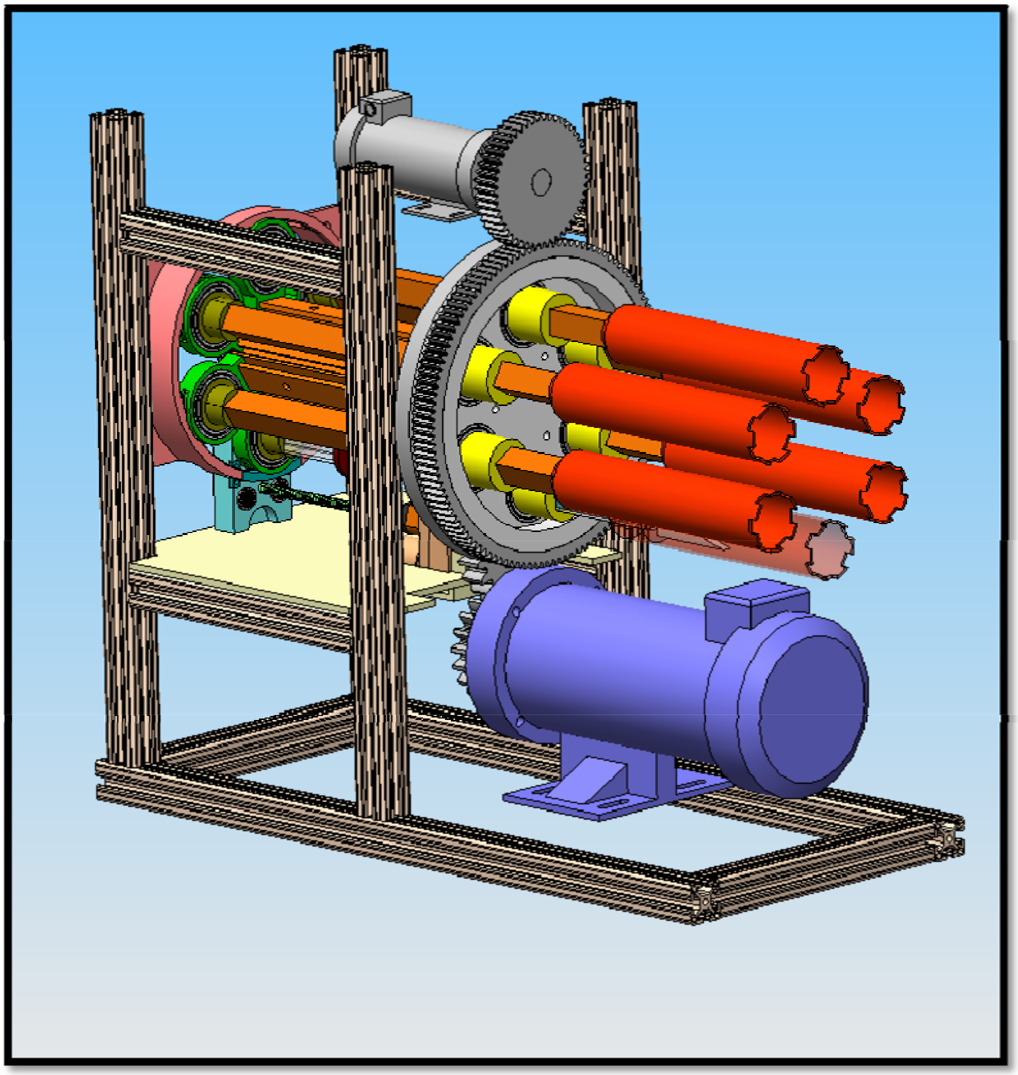

Figure 38. Frame for the core drill mechanism plus 8020 aluminum skeleton.

8.10 Gear Transmission System

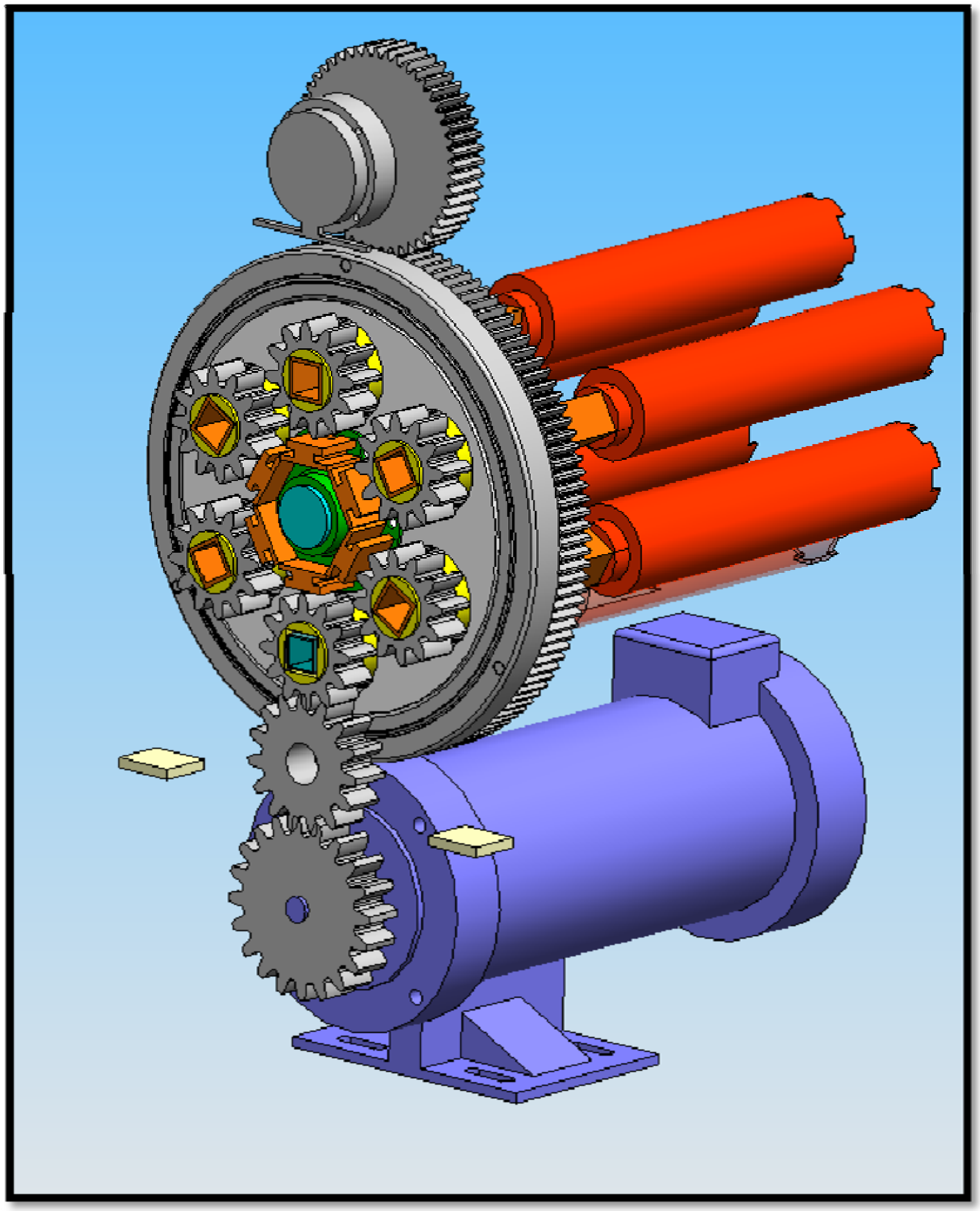

Figure 39. Gear transmission system.

The gear ratios can be changed to achieve the desire torque and to regulate the initial input from the 2 HP motor. Figure 38 shows the gear transmission system.

9. CONCLUSION

Physical and chemical characterization is the key element needed prior to the D&D activities. The dismantling process of nuclear facilities depends on the accuracy of this fundamental step. In the development of this technical report, the following conclusions have been made:

- Several technologies and methodologies are available for the performance of characterization. However, some situations will require special planning and need highly skilled engineering. These non-conventional techniques are expensive but more than justified for the protection and safety of all the personnel involved in the process as well as the areas near the nuclear facility.
- An automated technology to handle the difficult task of characterizing nuclear stacks does not yet exist. Currently, direct manual methods by human workers are the preferred approach. This can be accomplished only at great risk because the stacks that are in a much deteriorated physical condition and/or contain high levels of contamination.
- The SCS characterization system will provide with the necessary elements to successfully execute the characterization of a nuclear stack. However, more experimentation for validation is necessary in order to guarantee the efficiency of the characterization tools integrated to the SCS.
- The material selected for the smear process has proven to be efficient for the swipe operations. In addition, the actuating forces utilized on the smear pads are safe and no major modifications are needed on the SCS's smear sampler.
- The computer software selected to control the actuators of the SCS was shown to be efficient for controlling and data logging. Further work needs to be done in order to fully integrate all the electrical and mechanical components of the SCS.
- The core drilling mechanism represents a great challenge in terms of design. However, the design proposed in this technical report completely satisfies all the requirements for the core drilling operations in the characterization of a nuclear chimney.

10. REFERENCES

1. International Atomic Energy Agency. Technical report series number 440, Dismantling of Contaminated Sacks at Nuclear facilities.
2. International Atomic Energy Agency. Technical report series number 389, Radiological Characterization of the Shut Down Nuclear Reactors for Decommissioning Purposes.
3. U.S. Department of Energy, Office of Environmental Restoration, Decommissioning Hand Book, 1994.

APPENDIX

A.1 Experimental Procedure

A.1.1 Materials

- Regular foam, 1" thick (Figure 39)
- Double sided foam tape, 1/8" thick (Figure 40)
- Double sided foam tape, 1/4" thick (Figure 40)
- Double sided ribbon tape (Figure 40)

Figure 40. Regular foam 1" thick.

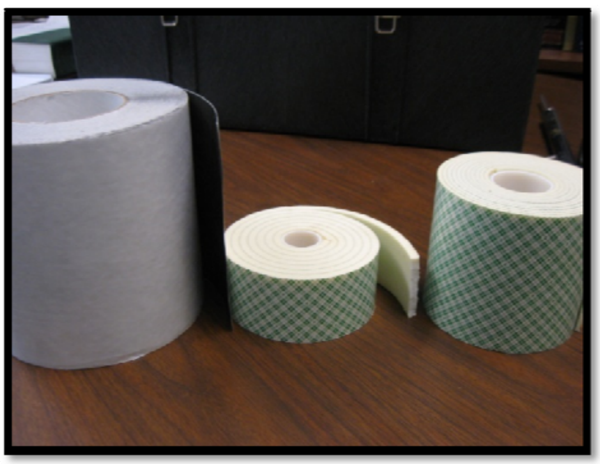

Figure 41. Double sided ribbon tape (left), double sided foam tape 1/4" thick (middle), double sided foam tape 1/8" thick (right).

A.1.2 Tools

- Arch punch, 44 mm (1.7”) (Figure 41)
- Punch cutting pad (polypropylene), 12” x 12” x ½” (Figure 41)
- Spring-loaded force gage (Figure 42)
- ABS pads (Figure 43)
- SCS smear carousel
- Laboratory scale
- Hammer
- Safety glasses

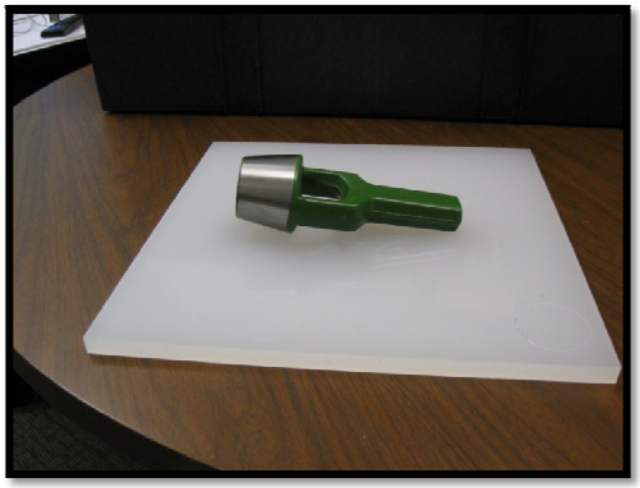

Figure 42. Arch punch (44 mm) and punch cutting pad (polypropylene, 12” x 12” x ½”).

Figure 43. Spring-loaded force gage.

Figure 44. ABS pads.

A.1.3 44 mm Foam Pads

1. Place the foam material on the punch cutting pad.
2. Carefully, using the arch punch, apply force (compression) on the foam material by lightly hammering it with a hammer (or by hand).
3. Before retrieving the arch punch, rotate the tool, applying force (compression) until the punch cutting pad is reached.
4. Repeat the same procedure on the double-sided foam tape (1/4" & 1/8") and the sticky ribbon.

A.2 Steps to Prepare the Carousel Pads

1. Holding the sticky ribbon by the paper that covers one of the sticky sides, place the sticky face of the ribbon on the ABS pad of the carousel. Remove the paper.
2. Place the desired foam material, double-sided (1/4" or 1/8") foam tape or the regular 1" foam, and place it on the uncovered face of the ribbon.
3. Repeat step 1 and place it on the remaining face of the foam. Do not remove the paper on the ribbon until prior to execution (Figure 44).
4. Place the prepared ABS pad on the sliding rod of the carousel.

Figure 45. Carousel pads (regular foam configuration).

A.3 Measuring Deployment Force

This part of the experiment will evaluate the reliability of the pads, made of several materials as explained in the previous section. The maximum capacity of the actuator connected to the SCS's smearing carousel is 3.4 pounds. A spring-loaded force gage will be connected to the prepared carousel pad and 3 pounds of force will be applied to it. The experiment will determine if this force is necessary to collect contaminants without breaking the components of the pad. The following are the basic steps of the experiment:

1. Place the prepared carousel pad on a desired surface.
2. Connect the force gage to the pad.
3. Manually apply force (compression) until force gage reads 3 lbf.
4. Observe condition of the pads.
5. Record observations.
6. Retrieve following the steps described in the following section and record the condition of the pads.

A.4 Measuring Retrieval Force

This part of the experiment will evaluate the ability of a 3.4 lbf actuator to retrieve the carousel pad from a desired surface. Following the deployment force experiment, 3.4 lbf in tension will be applied to the carousel pad to determine the adhesive properties of the ribbon tape. The following are the basic steps of the experiment:

1. Connect the force gage to the prepared carousel pad.
2. Manually apply force (tension) until force gage reads 3 lbs.
3. Observe condition of the pad.
4. Record observations.

A.5 Measuring the Amount of Material Removed

For several configurations of the carousel pad (ribbon-foam-ribbon or ribbon-double sided tape-ribbon), the amount of material removed will be measured. This will be done by simply weighing the prepared carousel pad before and after deployment operations. The steps are described as follow:

1. Carefully calibrate the laboratory scale and set it up to four decimal places.
2. Place the prepared carousel pad on the scale, wait 30 sec and record the value read on the digital screen.
3. After operations, carefully repeat the previous step and record the new weight.
4. Subtract the new weight from the initial and the result will represent the amount of loose contaminants collected from the surface.
5. Repeat all the previous steps for the configurations of ribbon-foam (1” thick)-ribbon, ribbon-double sided tape (1/4” and 1/8” thick)-ribbon.
6. Select the one with the greatest amount of loose contaminant collected.